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LSA LARGE AREA SILICON SHEET TASK  
ENHANCED ID SLICING TECHNOLOGY FOR SILICON INGOTS

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QUARTERLY REPORT

February - March  
1979

The JPL Low-Cost Silicon Solar Array Project is sponsored by the U.S. Department of Energy and forms part of the Solar Photovoltaic Conversion Program to initiate a major effort toward the development of low-cost solar arrays. This work was performed for the Jet Propulsion Laboratory, California Institute of Technology by agreement between NASA and DOE.



Menlo Park, California



April 1979

LSA LARGE AREA SILICON SHEET TASK  
ENHANCED I.D. SLICING

QUARTERLY REPORT #1  
February - March 1979

Project Manager: George Fiegl  
Prepared by: Dorothea Walters

April 1979

SILTEC CORPORATION  
Menlo Park, California

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## ABSTRACT

Efforts to make ingot technology cost effective for the production of low cost solar cells in the 1980-1986 timeframe have been divided into both the development of a continuous CZ growth process and advanced ingot slicing. While continuous CZ growth is being extensively explored with very promising results, very little work has been directed towards technological improvements of I.D. slicing -- the primary shortcoming of ingot technology.

The direction of this program is aimed towards the development and demonstration of enhanced I.D. slicing technology that will significantly increase the number of useable slices per inch of crystal over industry practice. This method will require a reduction of both blade and slice thickness. It will be accomplished by a combination of three key elements of slicing technology: ingot rotation with minimum exposed blade area, dynamic cutting edge control, and the use of prefabricated insert blades.

During the first quarter, design modifications were initiated on a Siltec slicing saw, Model E-1, with microprocessor controls. Hardware, to complete this conversion, is being fabricated.

Several runs were conducted on the engineering saw incorporating the method of ingot rotation. Ingots with diameters up to 6 inches were sliced successfully on a production saw.

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## **1.0 INTRODUCTION**

Currently, the existing silicon industry relies almost exclusively on slicing machines using the principle of I.D. (inside diameter) cutting utilizing a thin, externally tensioned, nickel-plated blade. The one key area where the I.D. concept has not compared well with other techniques is in the kerf loss. With present industry practices, typical production kerf loss for a 4-in. wafer slicing ranges from 300 to 400  $\mu$ , depending on machine type, blade, and process. As this loss is the major barrier to achieving low-cost solar cells using this method, a solution to this problem would have major impact on near-term cost goals as well as impacting the ultimate decision on ingot versus ribbon/web/film technology.

Accordingly, Siltec intends to develop and demonstrate a technique for low-cost slicing with a kerf loss of 130 to 180  $\mu$ , and combined kerf and slice thickness of less than 400  $\mu$ . This will be accomplished by a combination of new blade technology, cutting edge control, and ingot rotation with a minimum exposed blade area (Figure 1).

A prototype next generation slicing machine equipped for research purpose has already been under test in Siltec's development lab and has shown encouraging results. The saw, Siltec Model E-1, after some modifications, was brought to operational status. A series of wafers were sliced, serving as part of the wafer quality data base line.

Cutting with ingot rotation on ingots up to 6 in. in diameter was also performed on production saws.

## 2.0 RESULTS

### 2.1 Engineering Saw

Siltec's Model E-1 saw, after some modifications, was brought up to operational status. The modified saw, E-2, consists of the standard E-1 saw, except that the TTL controls have been replaced with a microprocessor (Figure 2).

Using a standard 15 in. X 5 1/8 in. X 0.013 in. blade, a series of wafers were sliced utilizing both conventional and rotating ingot slicing techniques. These wafers will become a part of the wafer quality data base line.

It was decided, for the present, not to convert the engineering saw to the 16 5/8 in. heads, primarily due to the fact that minor loss in validity of wafer comparison would be outweighed by the cost savings of not converting the saw (~ \$4,000).

A variable flow pump has been ordered which will allow experiments to be made with blade coolant, without affecting the production slicing coolant supply.

### 2.2 Ingot Rotation Mechanism

The ingot rotation mechanism was designed and built as a Siltec-funded project, but it has received little use due to priorities in other areas. During this first quarter, the unit was checked out on a production saw and was used in the slicing of ingots in a variety of sizes. By comparing wafers sliced during the initial development of the project with those produced during the February check-out, it was apparent that the period of storage had no adverse effect on the operation of the mechanism (Figure 3).

The ingot rotating mechanism was used, as stated above, on a 16 5/8 in. production saw to slice a set of 6 in. diameter

demonstration wafers as well. These wafers were subsequently shown by Siltec at the 12th Project Integration Meeting.

#### 2.3 Special Blades

Considering that one of the main advantages of rotating the ingot in wafer slicing is that the depth of the cut is half that of conventional slicing, special blades have been ordered in accordance with our plans for minimum exposed blade area. The saw head which we have selected in this program is a standard 12-in. size. For the slicing of the 100 mm DIA ingot, a 4 3/4 in. I.D. is required - the resultant blade size is 12 in. X 4 3/4 in., a nonstandard size. Tooling, to produce such a blade, has been ordered along with the initial order of blades from three different diamond patterns.

Several other special blades were ordered as well for the 15-in. head currently mounted to the engineering saw (Figure 4).

#### 2.4 Record Keeping

In the anticipation of keeping accurate, well-documented records, several trial forms were drawn up, and a procedure has been established for qualifying wafers. Examples of these tests will appear in future reports.

### **3.0 CONCLUSIONS**

Siltec is currently using the bevel-edge technique to determine the depth of work damage to the surface of the wafer. While this technique is definitive, it is also quite time-consuming. With the large quantity of wafers generated during the course of this program which will require inspection, a more expedient method will have to be developed.

#### **4.0 PROJECTION OF ACTIVITIES**

Variable surface speed of cutting and subsequent reduction of surface damage are areas of primary interest. Work particularly on these items is commencing.

Other areas of action are:

- . Completion of all design work and fabrication of the ingot rotation mechanism, and subsequent demonstration of the process.
- . Continued development of the blades, including demonstration of both special order and conventional blades.
- . Perform slice surface and blade quality analyses, holding sample wafers with appropriate identifying data.

APPENDIX I

Figures

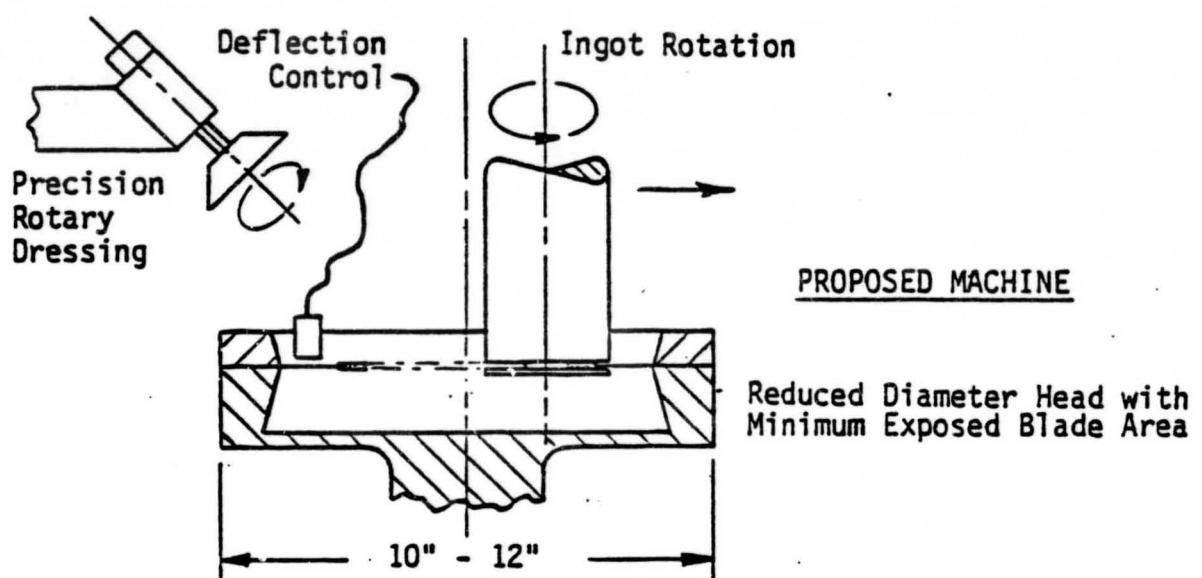
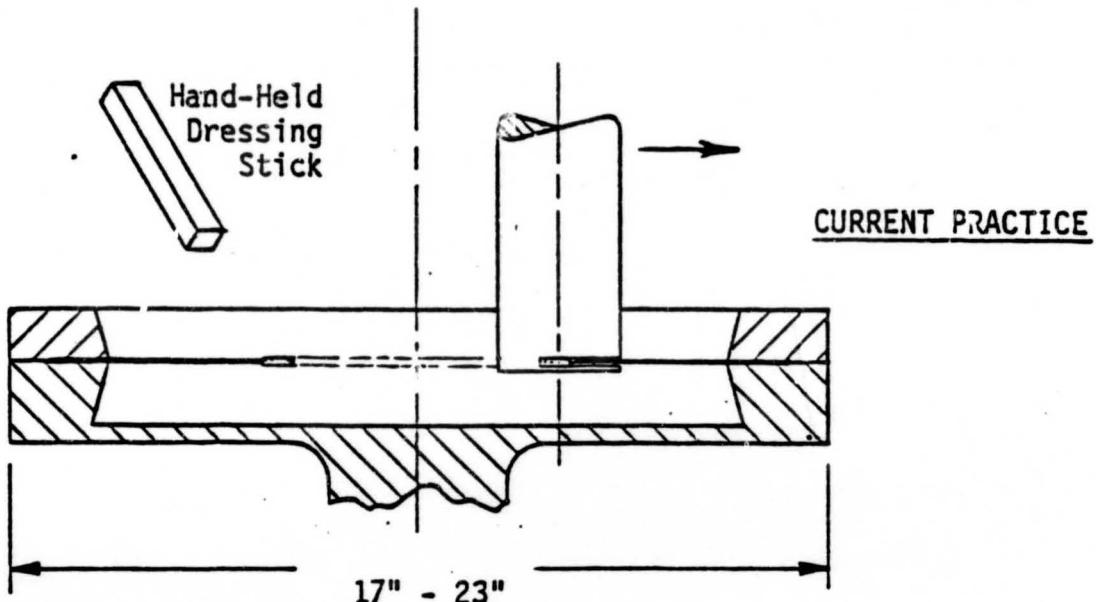
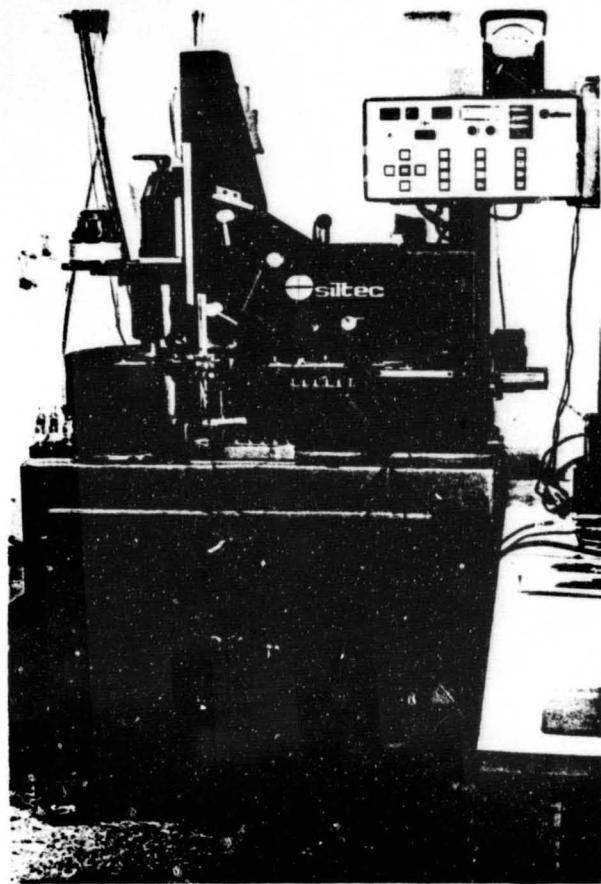
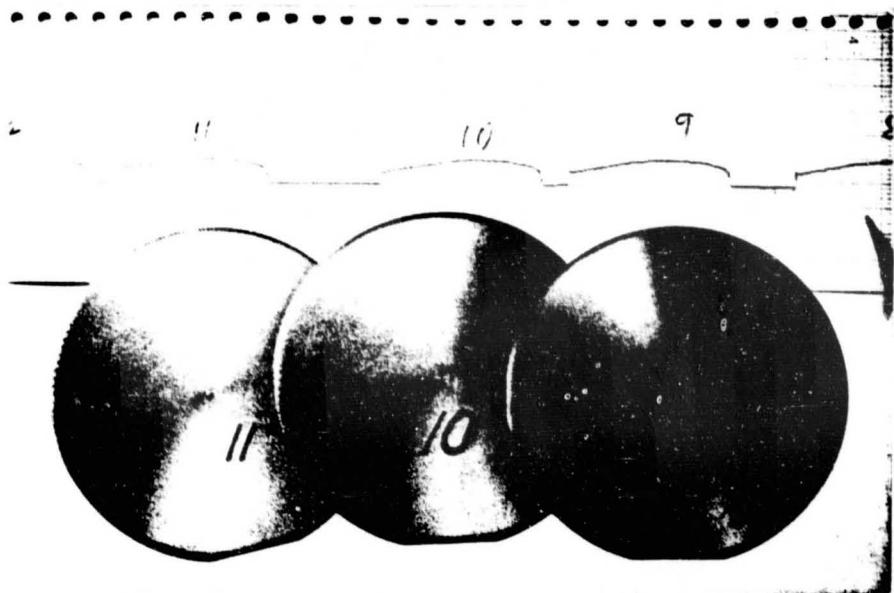


Figure 1: Blade head configuration; comparison of the system used in current practice with the proposed technology, incorporating ingot rotation, cutting edge control, and a minimum exposed blade area.



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Figure 2: Overall view of the modified Siltec Engineering Saw, Model E-2, with microprocessor.



**Figure 3:** Close-up view of wafers cut with ingot rotation.  
In the background is a graph from blade position monitor.

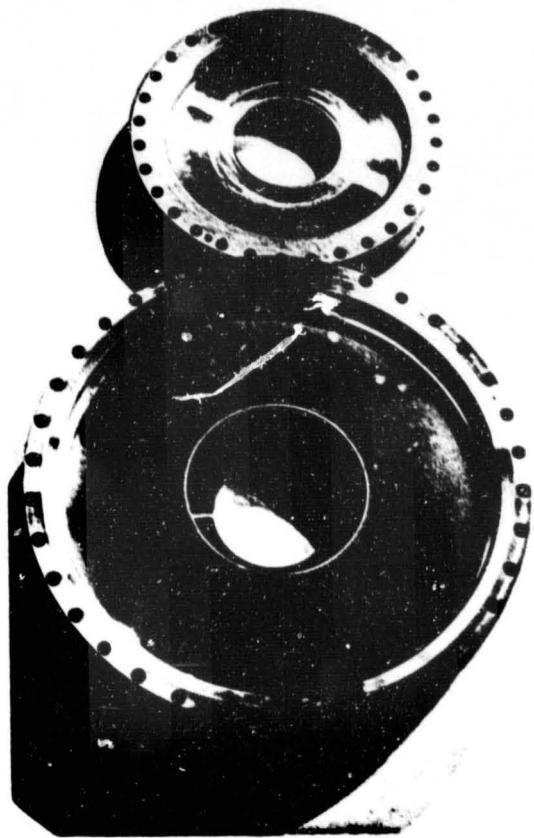


Figure 4: Comparison of small and large diameter blade and head assemblies.

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APPENDIX II

New Technology

No new technology was generated during this reporting period.

### APPENDIX III

#### Summary of Characterization, Design, and Economic Analysis Data

No data for characterization, design, or economic analysis were developed during this reporting period.

APPENDIX IV

Milestones

NEAR-TERM IMPLEMENTATION OF FLAT PLATE PHOTOVOLTAIC COST REDUCTION

UNDER THE LOW-COST SOLAR ARRAY PROJECT

PROGRAM PLAN

(Revised December 20, 1978)

**ENHANCED INTERNAL DIAMETER SLICING TECHNOLOGY FOR SILICON INGOTS**

Page 1 of 4

Statement of Work	MONTH																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
<b>TASK I: INGOT ROTATION CUTTING DEVELOPMENT</b>																		
A. Design, to Convert a Siltec Slicing Saw, Model E-1, with Microprocessor Controls																		
. Sliding Way Modification																		
. Precision Drive Table																		
. Variable Speed Motor																		
. Reduced Dia. Blade and Blade Deflection Monitor																		
B. Fabricate Hardware, as Described in "A", Task I																		
C. Demonstrate Ingot Rotation, Cutting on 10 cm Dia. Ingot with Conventional ID Blades and Achieve Kerfs of <200 Microns																		
D. Demonstrate Ingot Rotation Cutting on 10 cm Dia. Ingot with Conventional ID Blades of Minimum Exposed Blade Area and Achieve Kerf of <200 Microns																		
<b>TASK II: BLADE DEVELOPMENT</b>																		
A. Obtain Prefabricated Diamond Cutting Inserts of Required Specification																		
B. Assemble Blades																		
C. Demonstrate Ingot Rotation Cutting and Achieve Kerfs of <178 microns																		

Reference: JPL's RFP No. Z-2-2900-113

NEAR-TERM IMPLEMENTATION OF FLAT PLATE PHOTOVOLTAIC COST REDUCTION

UNDER THE LOW-COST SOLAR ARRAY PROJECT

PROGRAM PLAN

(Revised December 20, 1978)

ENHANCED INTERNAL DIAMETER SLICING TECHNOLOGY FOR SILICON INGOTS

Page 2 of 4

STATEMENT OF WORK	MONTH																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
<p><u>TASK III: DYNAMIC BLADE CONTROL DEVELOPMENT</u></p> <p>A. Design Hardware for a Blade Position Sensor and a Blade Position Controller</p> <p>B. Fabricate and Install Blade Position Sensor and Blade Position Controller on Existing Siltec E-1 Saw, as Described in Task I, "B" (for Edge Profile)</p> <p>C. Demonstrate Ingot Rotation Cutting on 10 cm Dia. Ingot Utilizing the Blade Position Sensor and the Blade Position Controller, as Described in "B", Task III, and Achieve Kerf of 150 Microns</p> <p>D. Design Hardware to Implement a Rotary Blade Dressing Fixture for Blade Edge Dressing.</p> <p>E. Fabricate and Install on Existing Siltec E-1 Saw, used in the Program</p> <p>F. Demonstrate Ingot Rotation Cutting on 10 cm Dia. Ingot Utilizing the Rotary Dressing Fixture Fabricated, as Described in "E", Task III, and the Blade Controller and Achieve Kerf of 150 Microns</p>																		

NEAR-TERM IMPLEMENTATION OF FLAT PLATE PHOTOVOLTAIC COST REDUCTION

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(Revised December 20, 1978 )

**ENHANCED INTERNAL DIAMETER SLICING TECHNOLOGY FOR SILICON INGOTS**

Page 3 of 4

STATEMENT OF WORK	MONTH																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
<b>TASK IV: PRODUCTION DEMONSTRATIONS</b>  A. Demonstrate the Utilization of Saw Modification in Tasks I, II, and III and Obtain Kerf Losses of 140 Microns and Better than 95% Wafer Yield  B. Verify Machine Productivity of 1,250 Wafers/24 Hour Day, Blade Maintenance of 600 Slices/Dressing, and a Lifetime of 4,000 Slices/Blade on 10 cm Dia. Ingots *  C. Obtain from "B", Task IV, a Data Base and Production Experience for Reduced Kerf ID Slicing																		
<b>TASK V: PERFORM SLICE SURFACE AND BLADE QUALITY ANALYSES</b>  A. Utilization of Surface Profilometry B. Utilization of Scanning Electron Microscopy C. Utilization of Optical Microscopy D. Chemical Etching Analysis E. Utilization of Infrared Spectroanalyses F. Utilization of X-Ray Topography G. Mechanical Surface Preparation (Lapping and Polishing)																		

Reference: JPL's RFP No. Z-2-2908-113

\*Tasks I, II, and III operational at end of Month 14

NEAR-TERM IMPLEMENTATION OF FLAT PLATE PHOTOVOLTAIC COST REDUCTION

UNDER THE LOW-COST SOLAR ARRAY PROJECT

PROGRAM PLAN

(Revised December 20, 1978)

ENHANCED INTERNAL DIAMETER SLICING TECHNOLOGY FOR SILICON INGOTS

Page 4 of 4

STATEMENT OF WORK	MONTH																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
TASK VI: PROVIDE SAMPLE WAFERS AND BLADE STOCK FROM ALL EXPERIMENTAL, DEVELOPMENT, AND DEMONSTRATION RUNS (HALF OF EACH RUN) WITH APPROPRIATE IDENTIFYING DATA																		
TASK VII: PROVIDE DOCUMENTATION																		